Suppression of Meszaros' Effect in coupled DE

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Abstract. A phaenomenological DM–DE coupling could indicate their common origin. Various constraint however exist to such coupling; here we outline that it can suppress Meszaros' effect, yielding transfered spectra with a softer bending above $k_{hor,eq}$. It could be therefore hard to reconcile these models with both CMB and deep sample data, using a constant spectral index.

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A tenable cosmological model must include at least two dark components, Dark Matter (DM) and Dark Energy (DE); yet only hypotheses on their nature exist; if DM and DE are physically unrelated, their presently similar densities are purely accidental.

Attempts to overcome this conceptual deadlock led to suggest, first of all, that DE has a dynamical nature [1]. Interactions between DM and dynamical DE [2], [3] might then partially cure the problem, keeping close values for their densities up to large redshift. This option could also be read as an approach to a deeper reality, whose physical features could emerge from phenomenological limits to coupling strength and shape.

A longer step forward was attempted by [4], suggesting that DM and DE are a single complex scalar field, being its quantized phase and modulus (*dual–axion* approach). Instead of introducing new parameters and limiting them through data fitting, this option, although cutting the available degrees of freedom, still allows to fit CMB constraints [5].

Here, however, we keep on the phenomenological side and discuss constraints to DM–DE interactions. This will have a fallout also on the *dual–axion* approach, which does face a problem, because of the feature of the DM–DE coupling it causes.

Any baryon–DE coupling is ruled out by consequences similar to modifying gravity. Limits are looser for DM–DE coupling, whose consequences appear only over cosmological distances. Here we outline a new constraint on this coupling, arising from the early behavior of fluctuations, over scales destined to evolve into cosmic structures.

Fluctuations over these scales enter the horizon before matter–radiation equality and their growth is initially inhibited by the radiative component, then still behaving as a single fluid together with baryons. While fluctuations in the fluid behave as sonic waves, DM self gravitation is just a minor dynamical effect is respect to cosmic expansion. This freezing of fluctuation amplitudes until equality is known as *Meszaros effect*.

Here we wish to outline that DM–DE coupling can damp Meszaros effect, so that fluctuation growth, between the entry in the horizon and equality, is significantly enhanced. As a matter of fact, fluctuation freezing is essential, in shaping the transfered spectrum.

The freezing or its damping only marginally affect baryons and radiation. Therefore, while the transfer function changes, CMB spectra keep almost unaffected. All details

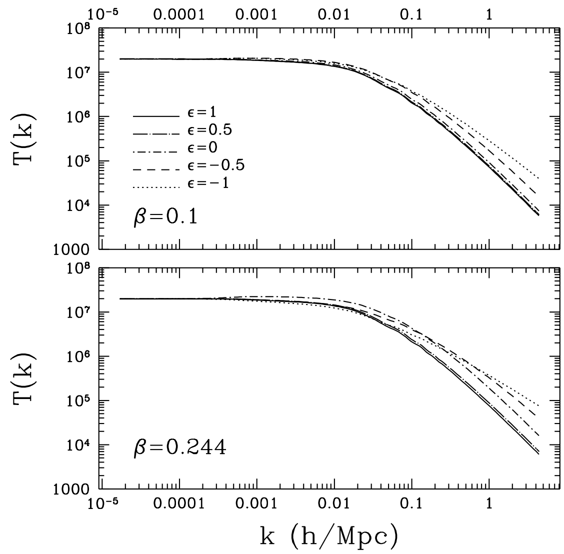

FIGURE 1. Transfer functions for different behaviors of DM–DE coupling with redshift and/or for different coupling normalization. The case $\varepsilon = 0$ corresponds to redshift independent coupling intensity. The case $\varepsilon = -1$ with $\beta = 0.244$ correspond to a coupling $C = 1/\phi$. Besides of the different slopes, notice the dependence on the model of the bending scale and, in particular, its dependence on the coupling strength, also in constant coupling models (dash–dotted lines).

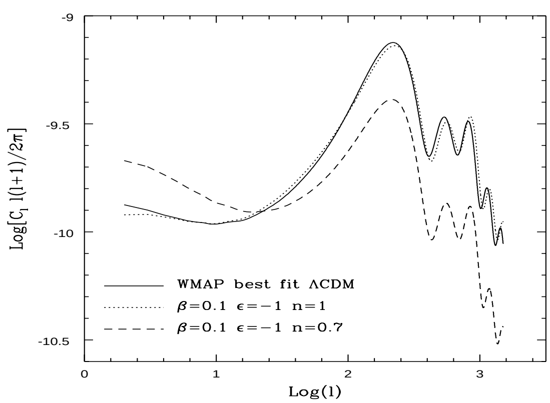

FIGURE 2. Anisotropy spectrum of the ΛCDM model yielding the best fit to WMAP3 data compared with the spectra for coupled models with $\beta = 0.1$ and $\varepsilon = 1$, for $n = 1$ and $n = 0.7$. In the former case one can expect to recover a reasonable fit to data by adjusting other model parameters. Taking $n = 0.7$, a value just acceptable to fit deep sample data, any fitting to CMB anisotropy data is apparently excluded.

on the way how these results are obtainable can be found in [6]. Let us however outline that what we wish to outline is a rather major effect, which allows to discard a class of models, *a priori*; no general data fitting, constraining parameters and/or showing specific model advantages, needs then to be performed here.

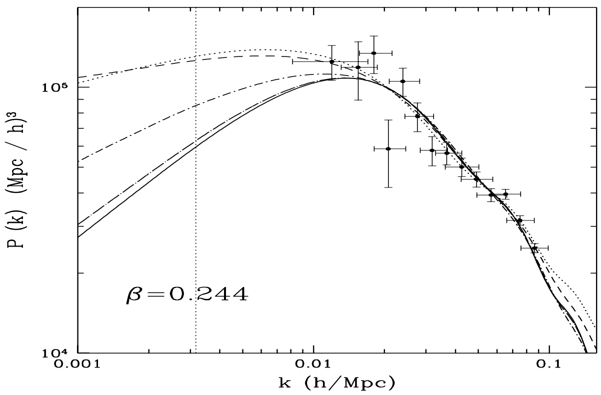

FIGURE 3. Comparison with SDSS digital survey data. Different curves refer to different ε's with the solid line ($\varepsilon = 1$) essentially coinciding with an uncoupled model. Constant coupling models ($\varepsilon = 0$) are described by dot–dashed curves. Negative ε's yield a further decrease of n. The vertical dotted line is the approximate scale where the Sachs & Wolfe C_l plateau begins.

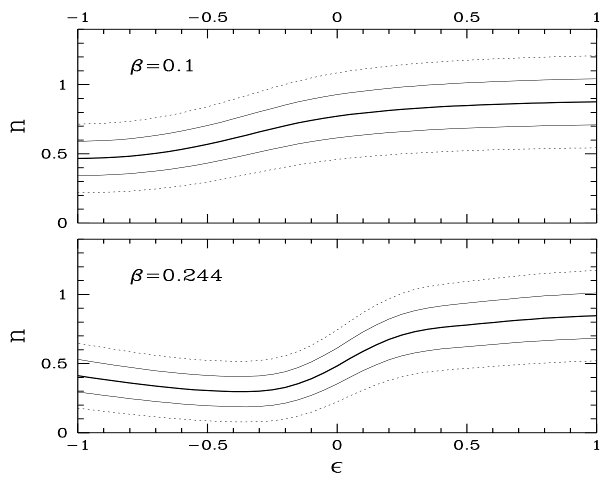

FIGURE 4. 1– and 2–σ intervals of n, when ε varies, for the β values in the frames

Accordingly, we keep to cosmological parameter values ensuing from WMAP3 best–fit [7], although deduced by assuming a ΛCDM model. In particular, we shall take $\Omega = 1$; the present value of the cold DM (baryon) density parameter will be $\Omega_{o,c} = 0.224$ ($\Omega_{o,b} = 0.044$); the Hubble parameter will be $h = 0.704$.

Our analysis here will however be restricted to SUGRA potentials [8]

$$V(\phi) = (\Lambda^{\alpha+4}/\phi^{\alpha}) \exp(4\pi\phi^2/m_p^2) \tag{1}$$

with $\Lambda = 100$ GeV. Here $m_p = G^{-1/2}$ is the Planck mass.

The background equations for coupled DE and DM, using the conformal time τ, read

$$\ddot{\phi} + 2(\dot{a}/a)\dot{\phi} + a^2 V_{,\phi} = C(\phi) a^2 \rho_c \ , \quad \dot{\rho_c} + 3(\dot{a}/a)\rho_c = -C(\phi)\dot{\phi}\rho_c \tag{2}$$

where the coupling is set by

$$C(\phi) = 4\sqrt{\pi/3}(\beta/m_p)\,(\phi/m_p)^{\varepsilon} = 4\sqrt{\pi/3}(\tilde{\beta}/m_p) \tag{3}$$

and therefore parametrized by β, ε or $\tilde{\beta}$. The *dual–axion* model naturally predicts a coupling $C = 1/\phi$, consistent with eq. (3) if $\varepsilon = -1$ and $\beta \simeq 0.244$.

Transfer functions are shown in Fig. 1 for $\beta = 0.1$ and 0.244 and various ε's.

The suppression of fluctuation freezing is obviously stronger for greater β (and increasingly negative ε values). For $\varepsilon = -1$, enclosing the case $C = 1/\phi$ when $\beta = 0.244$, the steepness of the transfer function, for $k > k_{hor,eq}$ is much reduced. The effect is still significant also for $\varepsilon = -0.5$, namely when $\beta = 0.244$.

While this occur, the CMB anisotropy spectum keeps a regular behavior, as is shown in Figure 2; here we compare WMAP3 data with C_l for $\beta = 0.1$, $\varepsilon = -1$ and $n = 1$ or 0.7 . Transfered spectra, compared with SDSS data (see Fig. 3), show in fact that $n \sim 0.5$–0.7 is needed to fit data.

In the case $\varepsilon \neq 0$, the discrepancy from unity of the spectral index n, assumed to be constant, is a measure of the distortion caused by the suppression of Meszaros effect.

If we take $n = 0.85$ at 1–σ as a threshold to discard a model, no $\varepsilon < 0$ model is allowed with $\beta = 0.244$, while $\varepsilon < -0.16$ are also inhibited with $\beta = 0.1$. At 2–σ's the situation is not much improved for $\beta = 0.244$, while lower values of ε are admitted for $\beta = 0.1$.

In particular, $C = 1/\phi$, as for the *dual–axion* model, is outside the range indicated. Modification to make this model consistent with data were however proposed [9].

The analysis was extended to models with positive ε, for which coupling rises while ϕ increases. A large deal of these models is apparently allowed.

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